

5      **WRITER DESIGN ELIMINATING TRANSITION CURVATURE FOR VERY  
NARROW WRITER WIDTHS**

**Field of the Invention**

         The present invention is directed to magnetic thin film head (TFH)  
devices for recording magnetic transitions on a moving magnetic medium and, more  
10 particularly, to a magnetic head that reduces transition curvature for very narrow writer  
widths.

**Background of the Invention**

         In the operation of a typical inductive TFH device, a moving magnetic  
storage medium is placed near the exposed pole-tips of the TFH device. TFH is  
15 composed of the magnetic poles and coils wrapping around the poles. During a write  
operation, a current flowing through the coils induces magnetic flux in the magnetic  
poles and generates the magnetic field across the gap between pole tips, so called writer  
gap. This field extends (i.e. is fringing) into the nearby moving storage medium,  
inducing or writing a magnetic domain in the medium. The part of fringe field  
20 extending not through the writer gap but from the side of the top pole to the bottom pole  
can erase edges of the neighboring written tracks and therefore negatively affect the  
quality of written tracks. Alternating current causes writing magnetic domains of  
alternating polarity in the storage medium.

         With ever increasing area densities there is a need for a head producing a  
25 very narrow track width and a very small bit cells down the track direction. The top  
pole width defines the width of the track and the writer gap length determines the bit  
cell length. As tracks get narrower, a curved part of the written track becomes a larger  
portion of the written track and is determined largely by the shape of the pole tip,  
magnetic properties of the material used at the writer gap length and write current. A  
30 fringe field extends into the nearby moving magnetic storage medium, inducing (or  
writing) a magnetic domain (in the medium) in the same direction. Impressing current

pulses of alternative polarity across the coil causes the writing of magnetic domains of alternating polarity in the storage medium.

Prior-art magnetic recording inductive TFH devices include top and bottom magnetic core pole layers, usually of the alloy Ni-Fe (permalloy), connected through a via in the back-portion area, and separated by a thin gap layer between the pole-tips in the front of the device. The bottom pole-tip is usually designed to be wider than the top pole-tip in order to prevent "wraparound" due to misregistration or misalignment, as taught by R. E. Jones in U.S. Pat. No. 4,219,855. Alternatively, one or both pole-tips are trimmed by ion-milling or by reactive ion etching (RIE) to ensure similar width and proper alignment. Such a technique is disclosed, for example, by Cohen et al. in U.S. Pat. No. 5,141,623. As the track width decreases in order to increase the recording density, the write head pole-tips must be very narrow. P. K. Wang et al. describe elaborate schemes to obtain pole-tips for writing very narrow track width, in IEEE Transactions on Magnetics, Vol. 27, No. 6, p. 4710-4712. November 1991.

One of the problems associated with the prior-art pole-tip designs is that during write operations, substantial noise is introduced along the track-edges (on the magnetic storage medium), which adds to the noise generated by the medium during read operations. During the write operations, significant portions of the intense magnetic flux lines, emanating from the corners and side-edges of the pole-tips, deviate from a direction parallel to the track's length. The non-parallel magnetic field magnetizes the medium in the wrong directions, giving rise to noise along the track-edges. This noise is usually characterized as "track-edge fringing noise" and is a major obstacle to increasing the track density. According to a paper by J. L. Su and K. Ju in IEEE Transactions on Magnetics, Vol. 25, No. 5, pp. 3384-3386, September 1989, the track-edge noise in this particular case extends about 2.5  $\mu\text{m}$  on each side of the written track. The high track-edge noise and wide writer width produced by the conventional design, limits its usefulness to relatively low track densities. As track density increases, the track width decreases, but the percentage of the curved transition relative to the track width increases.

U.S. Patent No. 5,673,163 (Cohen) discloses a pinched-gap magnetic recording thin film head where substantial contact is established between the bottom pole-tip 14 and top pole-tip 18 thereby pinching or confining a gap segment 16. In a preferred embodiment the bottom pole-tip 14 and top pole-tip 18 are in actual physical  
5 contact. In other embodiments a small gap may separate the bottom and top pole-tips. The small gap or separation should be small enough to prevent the magnetic flux lines from emanating significantly from the pole-tips in those regions. The separation of the pole-tips in those regions should not exceed about 25% of G, the vertical distance between pole-tips in the gap area. Preferably, the separation should not exceed 5% of  
10 G.

### **Summary of the Invention**

According to a first aspect of the invention, there is provided a magnetic transducer device having a bottom magnetic pole, a nonmagnetic gap layer deposited on the bottom pole and a top pole deposited on the gap layer. The top magnetic pole has an  
15 upper portion and a lower portion. The lower portion faces a surface of the bottom pole and has a middle section that is separated from the bottom pole by the gap layer by a first distance. The lower portion has end portions located at each end of the middle portion that are separated from the bottom pole by the gap layer by a second distance where the second distance is greater than 25% of the first distance.

20 According to another aspect of the invention, the second distance ranges from about greater than 25% to about 60% of the first distance.

According to still another aspect of the invention, the device has a width measured between a left and a right side of the top pole ranging from about 0.3 microns to about 1.5 microns.

### **Brief Description of the Drawings**

25 FIG. 1 shows an air-bearing surface (ABS) view of a magnetic thin film head according to a preferred embodiment of the present invention.

FIG. 2 shows an ABS view of a head according to a second preferred embodiment of the present invention.

FIG. 3 shows an ABS view of a head according to a third preferred embodiment of the present invention.

FIG. 4 shows an ABS view of a head according to a fourth preferred embodiment of the present invention.

5                   FIG. 5 shows an ABS view of a head according to a fifth preferred embodiment of the present invention.

FIGs. 6-10 illustrate a method for fabricating a head according to a preferred embodiment of the present invention.

10                   **Detailed Description of the Presently Preferred Embodiments**

FIG. 1 shows an air-bearing surface (ABS) view of a magnetic thin film head 10 for recording transitions on a moving magnetic medium (not shown) according to a preferred embodiment of the present invention. The head 10 includes a bottom pole 12, a top pole 14 and a gap 16. In a preferred embodiment the bottom pole 12 consists  
15 of layer 18 and a top layer 20 called a mesa. A non-magnetic regions 24 abuts each end of the magnetic region 22. The magnetic region 22 preferably has a width substantially equal to the width of the layer 26 or top pole 14. The top pole 14 preferably has a seed layer 26 on its end that faces the bottom pole 12. The seed layer 26 is shaped so that a gap GL1 exists between the top pole 14 and bottom pole 12. In addition, a smaller gap  
20 GL2 exists at each end portion 30 of the top pole 14. In a preferred embodiment, GL2 ranges from about 25% to about 60% of GL1. More preferably GL2 is about 60% of GL1. Preferably  $GL_2/GL_1 < 1.0$ .

In the preferred embodiment shown in FIG. 1, the end portions of the top pole 14 are rectangular in shape. The fabrication of a head according to the present  
25 invention will be described in greater detail hereinafter. The gap 16 is preferably filled by a nonmagnetic material such as silicon oxide, silicon nitride, nickel palladium,  $Al_2O_3$ ,  $Ti$ , titanium.

The head shown in FIG. 1 has a width TPWG that can range from about 0.3 microns to about 1.5 microns. In a preferred embodiment TPWG is about 0.5  
30 microns. The gap length GL1 is about one-third of TPWG. Thus, GL1 can range from

about 0.1 microns to about 0.3 microns and in a preferred embodiment is about 0.15 microns.

The top pole 14 is preferably made of magnetic material preferably Fe based alloys like NiFeCo, NiFe, FeTaN, FeAlN or any other iron nitrate with Hf, Zr, Pa additives. The seed layer 26 can be formed of the materials like those used in the top pole by sputtering, or electroplating. The shared pole of the bottom pole 12 is preferably made of Fe based alloy. The magnetic material 22 deposited on the shared pole is preferably formed of high moment Fe-based alloy. The nonmagnetic regions 24 are preferably formed of alumina, SiO<sub>2</sub>, SiN, Ti. Alternatively, the magnetic and nonmagnetic regions 22, 24 can be eliminated so that the bottom pole 12 is flat and does not have mesa.

FIG. 2 shows an ABS view of a head 100 according to a second preferred embodiment of the present invention. The head 100 according to this preferred embodiment is identical to that shown in FIG. 1 except for end portions 30 of the top pole 14. In this preferred embodiment the end portions 30 are shaped as wedges. Thus, GL2 ranges from about 60% of GL1 at its outer most point to GL1 at its inner most point.

FIG. 3 shows an ABS view of a head 200 according to a third preferred embodiment of the present invention. The head 200 according to this preferred embodiment is identical to that shown in FIG. 1 except for end portions 202. In this preferred embodiment, the surface of the end portions 202 that face the bottom pole 12 are angled so that its outermost point has a gap length GL2<sub>a</sub> and at its innermost point it has a gap length GL2<sub>b</sub>. In a more preferred embodiment, GL2<sub>a</sub> < GL2<sub>b</sub> < GL1. In a more preferred embodiment, GL2<sub>a</sub> is about 60% of GL1 and GL2<sub>b</sub> is about 80% of GL1. The segment 204 connected GL2<sub>a</sub> to GL2<sub>b</sub> is linear although it can also be curvilinear as shown in FIGs. 4 and 5. In FIG. 4 the segment is concave and in FIG. 5 the segment is convex. Overall what is important is that GL2 is less than GL1 and GL2 may have a range with the end portions of the top pole. In addition, the surfaces of the end portions that face the bottom pole may be parallel with the bottom pole or non-parallel with respect to the bottom pole.

The method of fabricating a head according to a preferred embodiment of this invention will now be described with reference to FIGs. 6-10. A shared pole material is first deposited on a reader gap. Deposition can be done by electroplating or any vacuum technique such as sputtering. The deposited material can be as thick as 2  
5 um to 5 um of the gap material which can be composed of alternating layers of magnetic and non-magnetic material, is then deposited on the pole material via electroplating (i.e., NiPd) or sputtering Al<sub>2</sub>O<sub>3</sub>, SiN, SiO<sub>2</sub>. The gap material is patterned with a photoresist layer and has a width less than the design width of the top pole. An ion mill is used to remove the gap material on either side of photoresist. The variety of writer gap slope  
10 angles can be reached through a careful selection of the mill angle and mill energy. A lift off operation removes the photoresist layer used in the definition of the writer gap shape. A seed layer, 20 and 30 and top pole, 14, defined in FIGs. 1 to 5, are deposited through a thick photoresist mask carefully aligned with writer gap feature (not shown in a drawing). The seed layer should have a magnetic moment B<sub>sat</sub> higher than 1 Tesla,  
15 preferably higher than the magnetic material used in the top pole. The seed layer thickness can be from 500 Angstroms to 300 Angstroms. The defines the structure of the first top pole. In the next step, a wet etch chemical removes the thick photoresist and is followed by an ion mill process to remove the seed layer.

After that another resist (not shown) is deposited to protect all the  
20 surfaces except the pole tip area. This step is necessary to implement a second mill process which removes the bottom pole material and defines the mesa under the writer gap. In the mill process, the thickness of top pole is reduced, therefore the plating has to be thick enough to get a final top pole thickness required by design.

After the mesa is defined, a nonmagnetic material is deposited adjacent  
25 to bottom pole and the top pole 14.

This path can be used for writers with a single top pole or writers with two piece top poles. In the last case the top pole layer is chemically mechanically polished to create a flat top surface as shown in FIG. 10.

Current writers implementing high moment materials ( $B_{sat} > 1.0$  Tesla)  
30 suffer from creating transitions that are curved. The situation worsens with the smaller

writer gaps, narrower TPWG and high write currents, as the curved part of transition becomes a significant part of the written track. The edge effects become dominant as the width of the top pole decreases and the curved part of the transition becomes a significant portion of the written track. The curved transition increases the transition parameter. The deterioration of the transition parameter adversely impacts the width of the pulse at half amplitude, termed also as PW50. The situation worsens even further at the higher bit per inch densities. Both transition parameter and PW50 are described on p. 213 and p. 133 in the "Theory of magnetic recording" by H.N. Bertram ed. by Cambridge University Press 1994.

10                   Buildup of the charges at the edges of the writer's top pole causes curving of the transitions. The present invention shifts the charge build up in a controlled fashion, down from the trailing edge at the edges of the gap and effectively straightens previously curved part of the written transition. High moment seed material assures higher field gradients compared to a structure with a flat top pole. The method  
15                   described above assures good control of the track curvature even for an extremely narrow writer widths, i.e.,  $TPWG=0.5-1.0\ \mu m$ .

                  The best results are observed with the seed layer material exceeding the saturation moment of the top pole material.

                  The above specification, examples and data provide a complete description of the  
20                   manufacture and use of the composition of the invention. Since many embodiments of the invention can be made without departing from the spirit and scope of the invention, the invention resides in the claims hereinafter appended.